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Space Administration

Jet Propulsion Laboratory
California Institute of Technology
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ISSM: Ice Sheet System Model

Large scale, high-resolution modeling of ice-sheet flow with data assimilation coupled with an ocean model

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Outline

1. Introduction
2. Current Implementation and results
3. Future capabilities.
4. Challenges and Perspectives

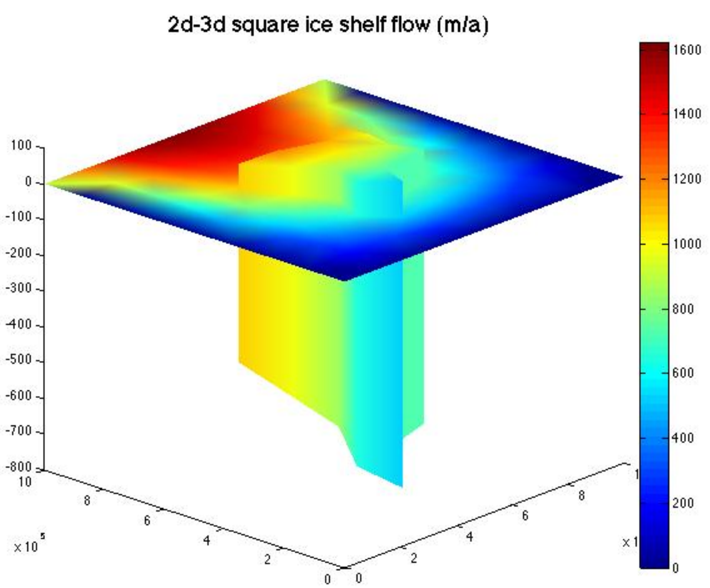
1. Introduction

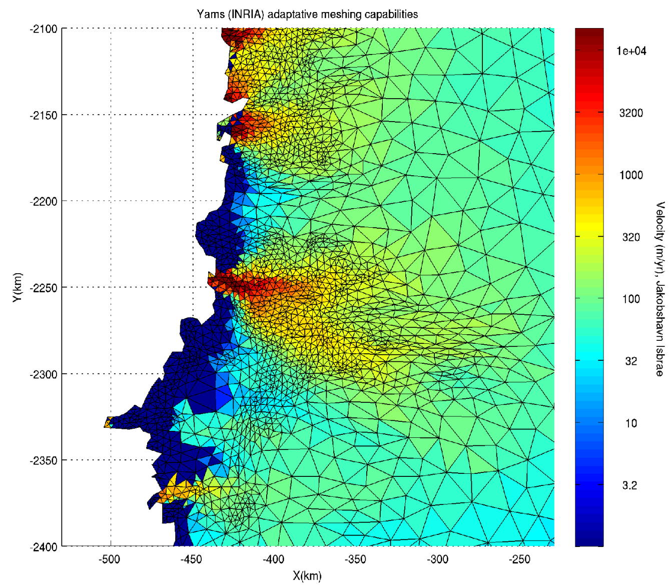
- ISSM (Ice Sheet System Model) initiated from JPL RTD effort (Larour, PI) and NASA IDS (Rignot, PI).
- ISSM is now funded by NASA MAP (Modeling and Prediction) (Rignot, PI).
- Only and first ice sheet modeling effort (with PISM) funded by NASA/MAP.

- ISSM is a JPL/UCI collaboration to develop large-scale, high-resolution ice-sheet modeling with remote sensing data assimilation, coupled with an ocean model.
- Data assimilation includes InSAR, GRACE and altimetry (ATM, ERS, Icesat).
- Ocean model is JPL/MIT ECCO2 derived from the MIT/GCM.
- ISSM offers large-scale capability (Antarctica), multi-scale (km glacier to 100-km ice sheet proper), multi-model (2d, 3d, 2d/3d coupled, full Stokes).

2- Current implementation.

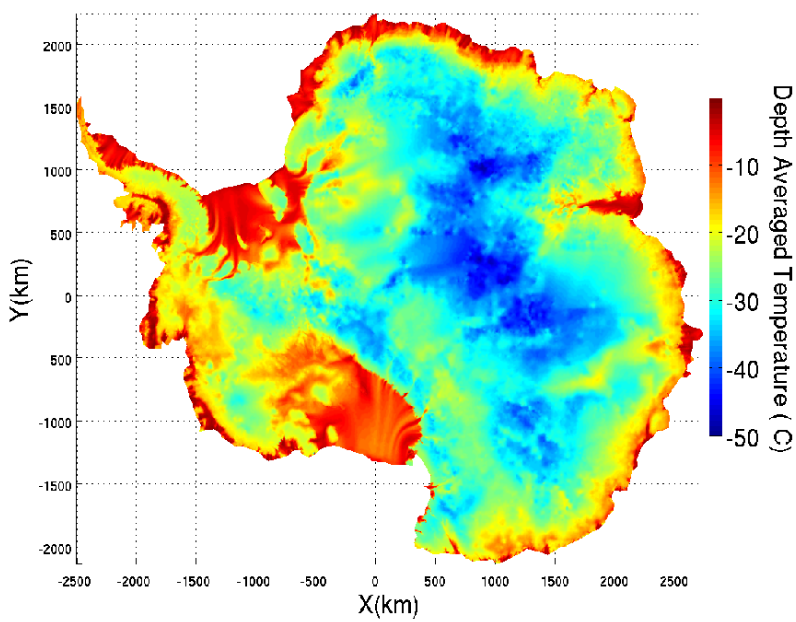
- 2D-3D higher-order modeling: Hutter's SIA, MacAyeal's shelfy-stream, Pattyn's higher order 3D, full Navier-Stokes 3D.
- Multi-model: different models are connected using Rigid Body Motion connectors, or method of penalties.
- Multi-scale: anisotropic mesh adaptation, Yams (INRIA, Pascal Frey).

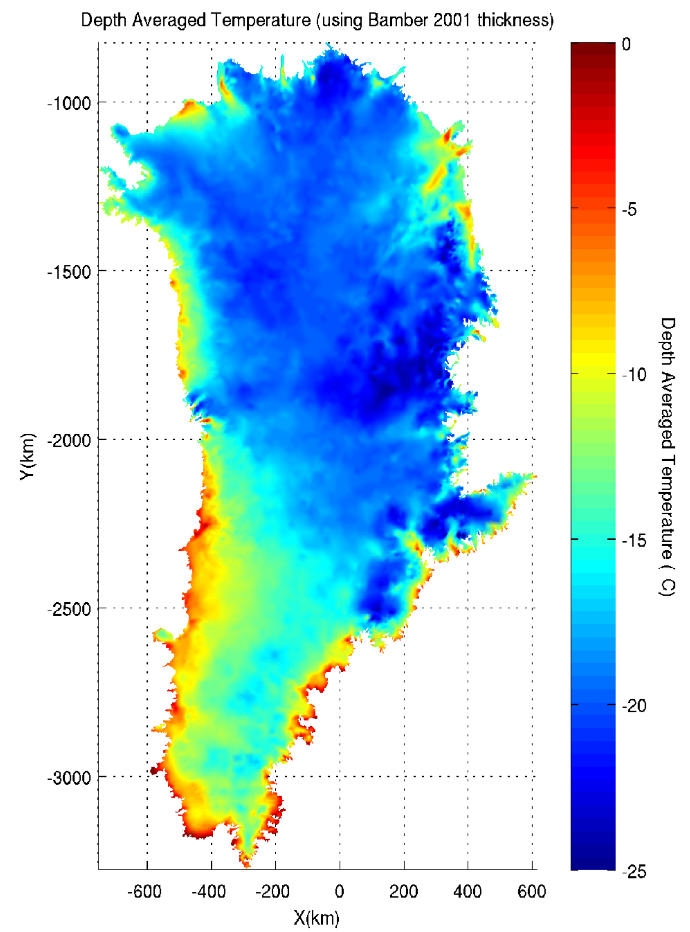




Thermal regime

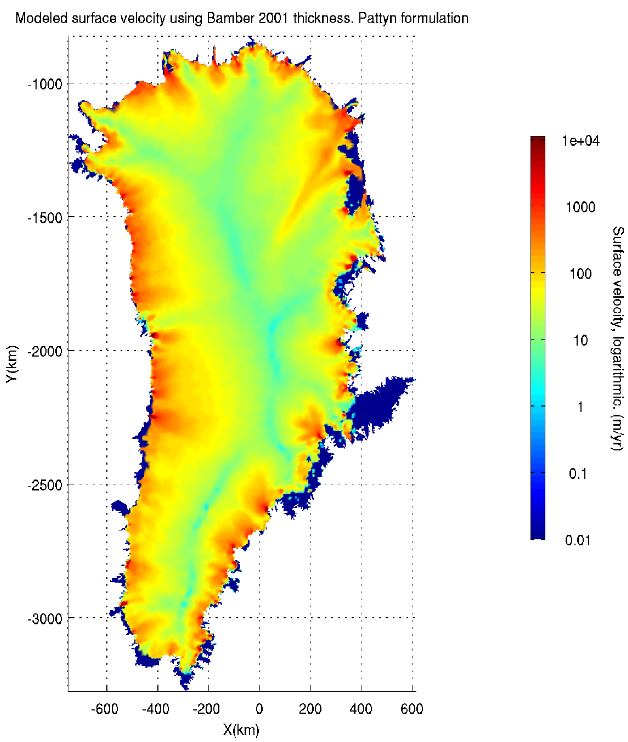
- Thermal regime: steady-state + transient.
  - Advection & conduction, no approximation.
  - SUPG stabilization.
  - Melting is a by product of thermal modeling using penalties.

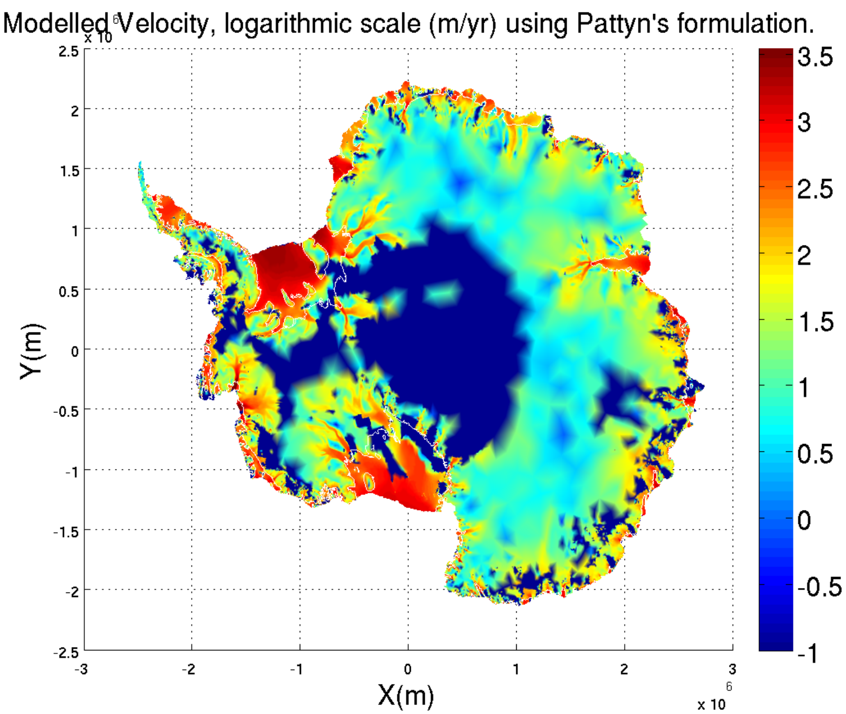




Spatial resolution and geographic coverage

- Large scale capability:
  - 5 million dof on 256 CPU cluster (shared or distributed memory).
  - Using Yams -> 1 km resolution on Antarctica's ice streams, < 1km resolution on Greenland basins, with 10 vertical layers.

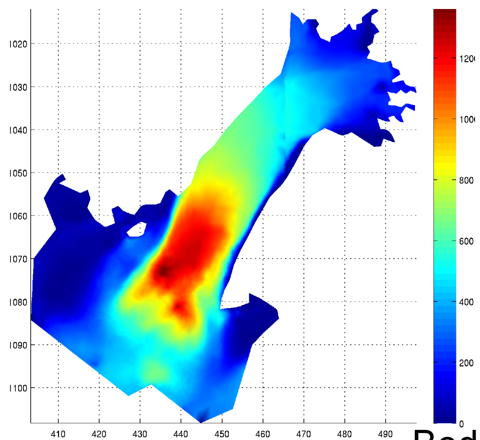




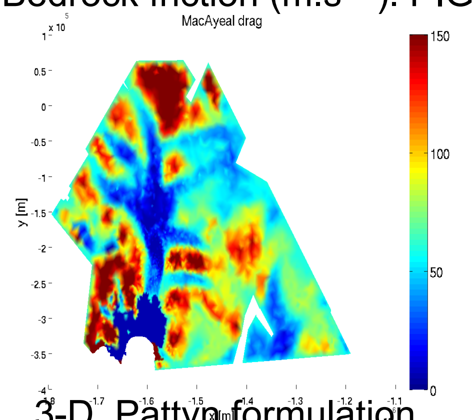
Data assimilation
Basin level

- Higher-order data assimilation: MacAyeal, Pattyn and Stokes formulations at the basin level.
- MacAyeal and Pattyn at the continental scale.

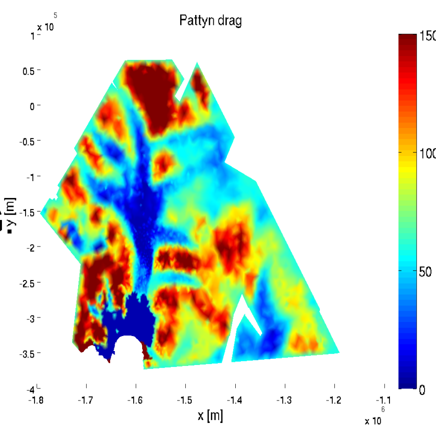
Modeled velocity (m/a). 79N.



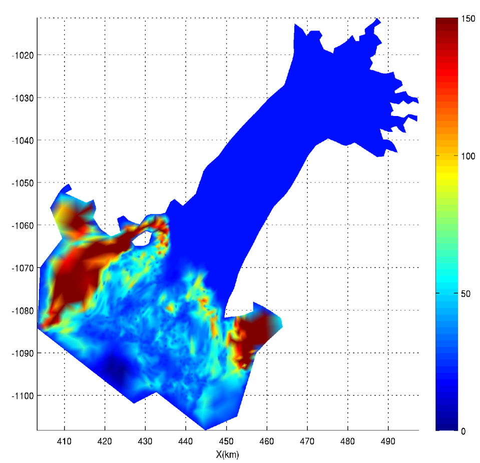
2-D. MacAyeal formulation.
Bedrock friction (m.s$^{1/2}$). PIG.



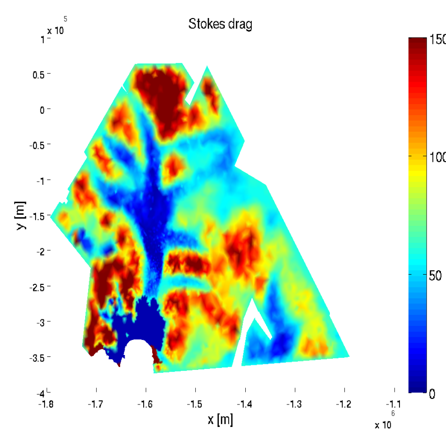
3-D. Stokes formulation.
Bedrock friction (m.s$^{1/2}$). PIG.

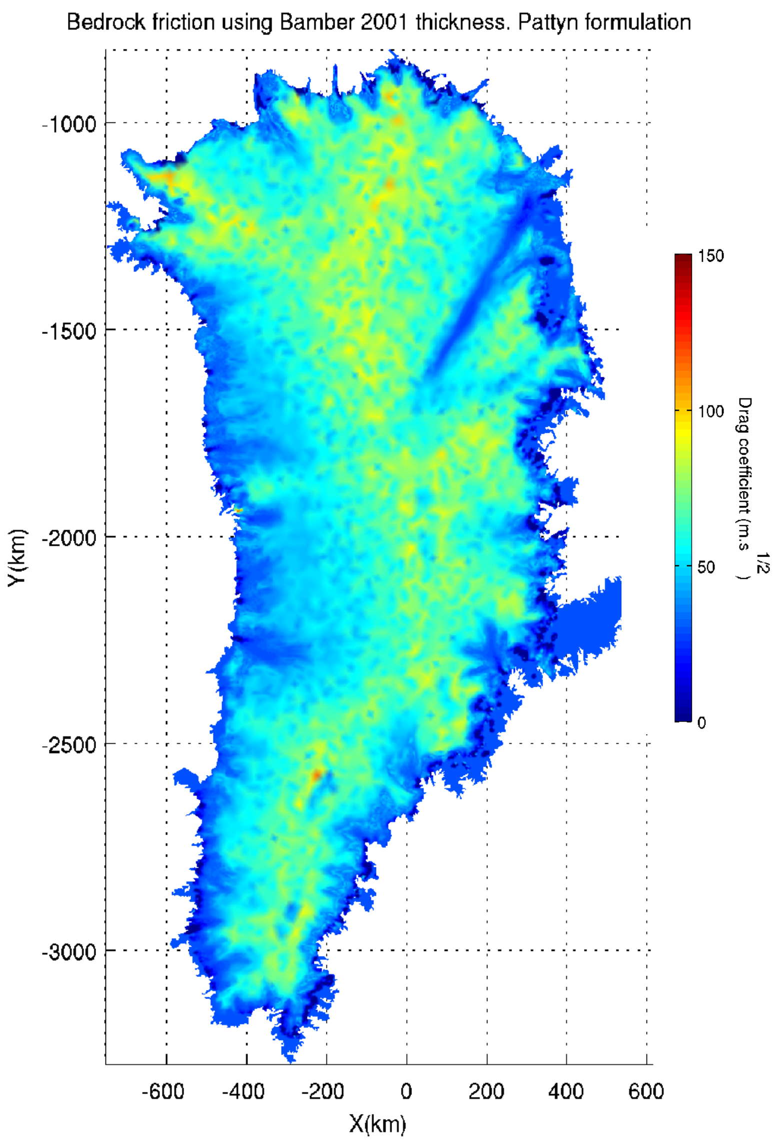


Bedrock friction (m.s$^{1/2}$). 79N.



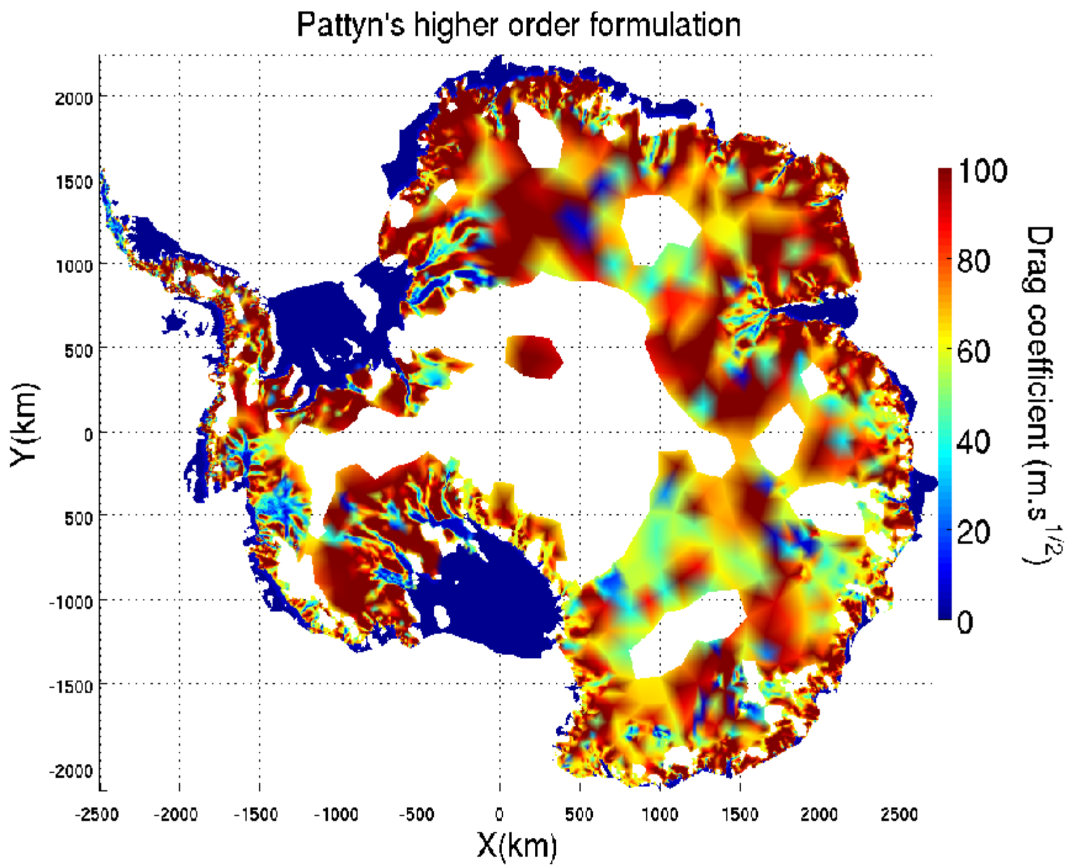
3-D. Pattyn formulation.
Bedrock friction (m.s$^{1/2}$). PIG.





Model:
- Data assimilation for basal drag, using surface velocity from InSAR (Rignot) + balanced velocities (Bamber 2001)

Run statistics:
-128 CPUS cluster. 12 h computation.
-500 m resolution at basins , 10 km inland.
-10 vertical layers.



Model:

- Data assimilation for basal drag, using surface velocity from InSAR (Rignot).

Run statistics:

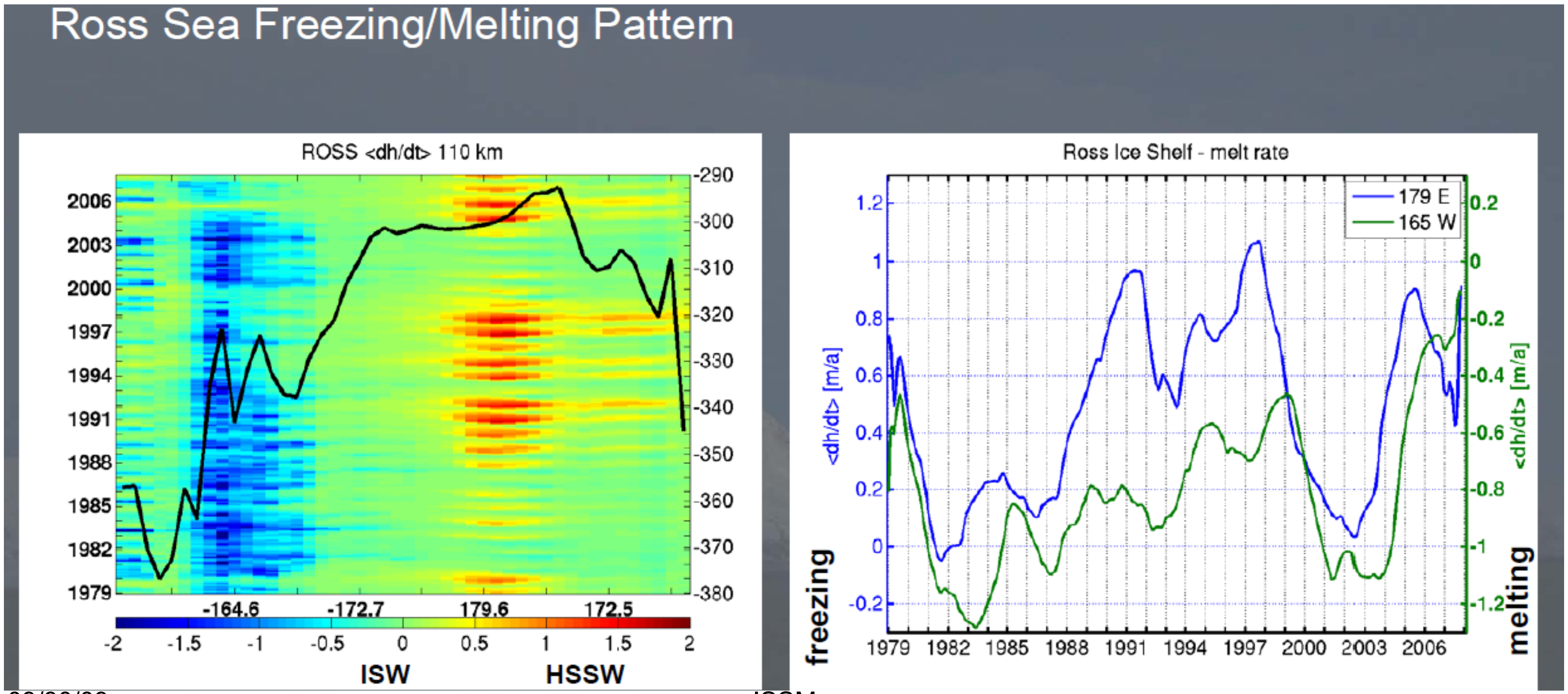
-128 CPUS cluster. 18 hr computation.

- 1.5km resolution at basins, 10 km inland.

-10 vertical layers.

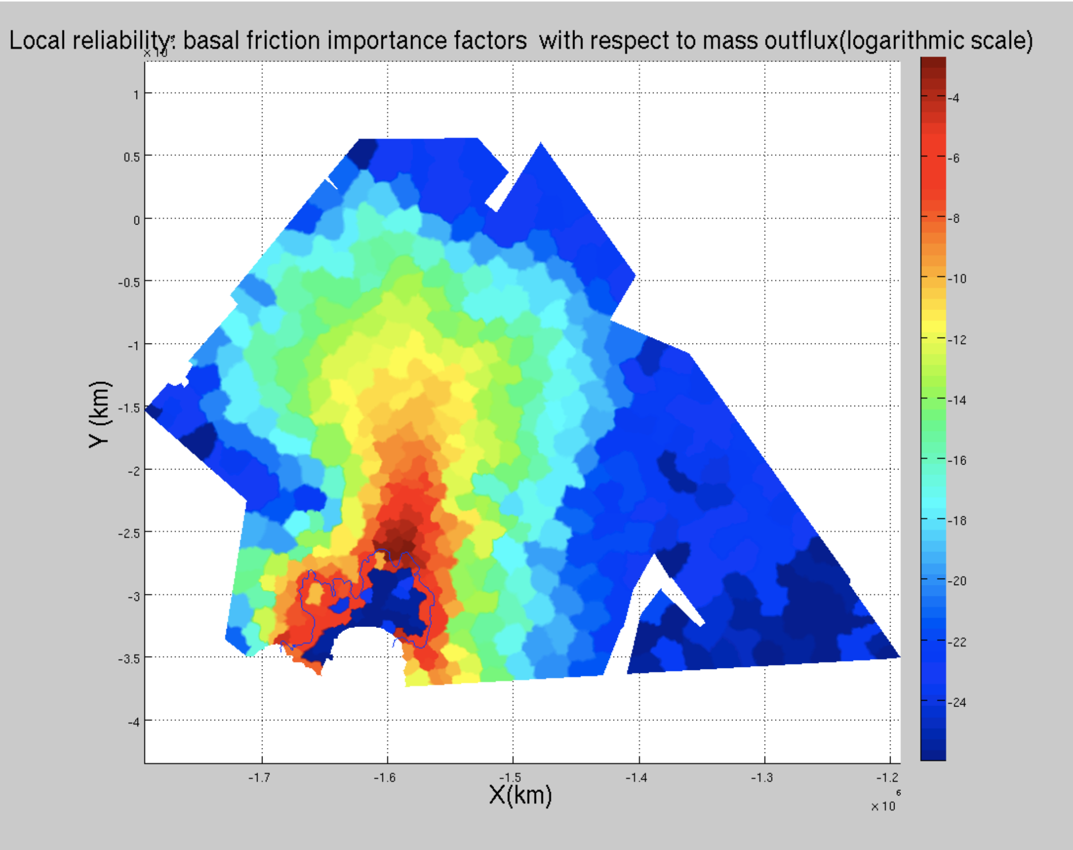
ISSM – ECCO2

- ECCO2 framework (using MIT GCM) is used to provide a coupling with the ocean.
  - melting under ice shelf cavities and at ice front implemented by Schodlock, 2005.
  - Other processes are being implemented (sub-glacial discharge, submarine melting of calving faces (Rignot et al., 2009)).



Sensitivity analysis

- Dakota in embedded mode (Sandia National Lab)
    - Local reliability methods
    - Monte-Carlo (Latin Hypercube)
    - Parameter studies
    - Optimization



3. Future capabilities.

- Moving boundary conditions:
  - Grounding line dynamics implemented at the 100 m spatial scale
  - Calving law
- Evolutionary model for basal drag combining hydrological modeling and data assimilation

4. Challenges and perspectives.

- Outstanding challenges for ice sheet modeling:

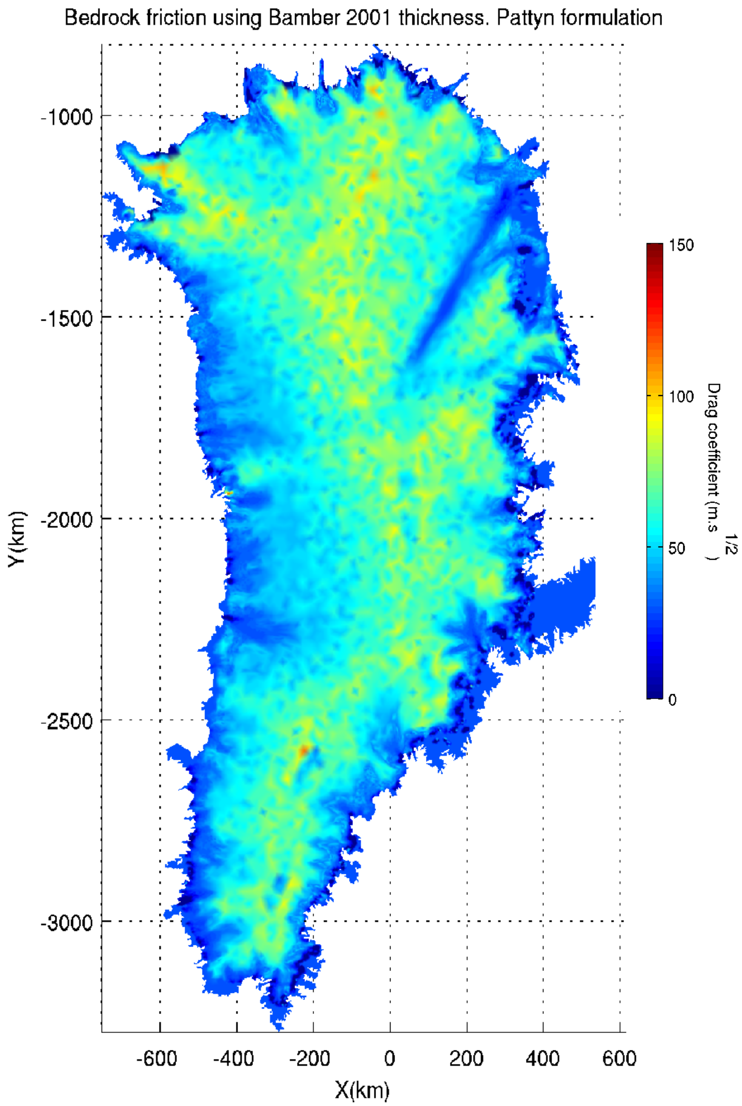
  - Prognosis: Even with data assimilation and control, these numerical models remain tunable, diagnosis models, not prognosis models.

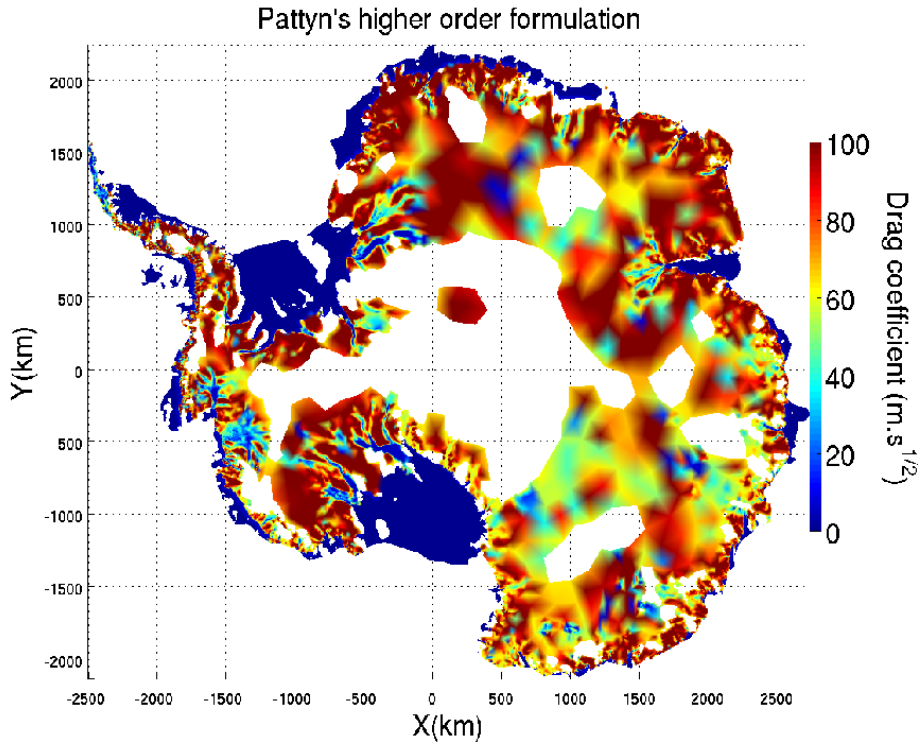
  - Glacier thickness: We need the depth below sea level, bed slope, and basic shape of glacier troughs of all major Greenland glaciers. We need major Cresis/Icebridge campaigns for thickness using radar and other tools where radar does not work (gravity?). Higher-resolution products remain TBD

  - Time series of ice velocity (InSAR and others) and ice surface elevation (Icesat, ATM, Cryosat) remain fundamental observables for constraining ice flow models.

  - Ice-ocean interactions are an important/dominant control of glacier changes. We need improved fjord bathymetry near glacier fronts to better constrain ice-sheet/ocean coupled models.


THANKS !





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